The 7-year variation in pressure is shown by curves 8 and 9, representing the Toronto and St. Louis series of observations. It has been found that the phases of the 7-year period in pressure are nearly synchronous over very extensive regions embracing areas as large as the United States. St. Louis well illustrates the character of this fluctuation for the interior of the country. The Toronto series carries the variation back to 1840. Observations at Providence extend the record back to 1832. This record shows pressure maxima in 1835 and 1840 and minima in 1837 and 1844. A tendency for high pressure slightly to precede low temperature, and vice versa, is clear from an inspection of the curves.

Curves 10 and 11 show fluctuations in the mean annual stage of the river at Cincinnati and Little Rock. The variations in the yearly amounts of precipitation over the watershed above these stations are well represented by these river-gage readings. The regularity of the 7-year cycle in the Little Rock record is remarkable and it is not surprising that this cycle has been observed in the fluctuation of this river at Fort Smith, as stated above. The curves show that low temperatures are associated with periods of maximum precipitation and high pressure. The curves of the latter are inverted with reference to the curve of temperature.

Records of high waters at Natchez, Miss., yield maxima as follows: 1814, 1823, 1831, 1836, 1842, 1849, and 1858, and minima in 1819, 1828, 1834, 1839, 1845, and 1855. The high stages of 1858–59 were general over the entire Mississippi watershed. At Cairo and St. Louis the 1858 stage exceeded the 1859 stage. In the upper Mississippi Valley, as shown by the record at Davenport and St. Louis, a pronounced maximum stage occurred in 1862 and a minimum in 1864, followed by a maximum in 1867. These fluctuations accord closely with those of temperature as shown by the Schott curve and with pressure as shown by the Toronto curve and the Providence observations.

A 7-YEAR PERIOD IN CROP YIELDS.

The yield of corn for the whole United States varies in a 7-year period. Maximum yields occurred about 1871, 1877, 1884, 1889, 1897, 1905, 1914, and 1920. These dates occurred at or shortly after the epochs of maximum precipitation. The importance from an economic point of view of this cyclical relationship between weather and crops can not be overestimated. Far-reaching effects resulting from this close relationship can also be traced in a 7 or 8 year period in industrial and business activity.

THE 7-YEAR PERIOD IN OTHER REGIONS OF THE GLOBE.

The 7-year period has been traced in European records of pressure. The dates of high and low winter pressure found by Maurer have been given above. The variations based on yearly means according to the researches of the writer are: Maxima, 1746, 1753, 1760, 1767, 1774, 1779, 1787, 1796, 1803, 1808, 1813, 1821, 1826, 1834, 1841, 1850, 1858, 1863, 1868, 1874, 1882, 1890, 1898, 1905, 1914. The dates of minima are: 1742, 1750, 1757, 1764, 1771, 1777, 1783, 1791, 1800, 1806, 1811, 1817, 1823, 1829, 1838, 1845, 1853, 1861, 1865, 1871, 1878, 1886, 1894, 1903, 1910. These epochs synchronize closely with those of the United States. On the other hand, the Iceland pressure varies oppositely, as follows: Maxima, 1844, 1854, 1859, 1866, 1871, 1878, 1887, 1894, 1901, 1909, 1916; minima, 1847, 1857, 1863, 1868, 1874, 1883, 1890, 1898, 1904, 1913.

The temperature in Europe varies generally opposite to that of the United States east of the Rocky Mountains. The records at Greenwich and Paris show maxima 1852, 1858, 1863, 1868, 1875, 1884, 1893, 1899, 1905, 1912; minima, 1854, 1860, 1865, 1871, 1879, 1888, 1895, 1902, 1909, 1917. This opposition between the temperatures of the United States and Western Europe is probably due to the periodical variation of the Iceland pressure. When the Iceland low is strongly developed, the winds over the eastern United States have a strong northerly component, while those of western Europe show an increase in the southerly component of the winds. On the other hand, when the Iceland pressure is high there is an increased frequency of cold, continental winds over western Europe while, at the same time, the winds over the United States have an increased southerly component.

The resultant direction of the wind at Providence, R.I.,[7] from 1830 to 1876 has varied in an approximately 7-year period. The years of extreme northerly deviation are 1831, 1837, 1842, 1847–1848, 1857, 1863, 1867, 1875. These years correspond closely to years of low temperature and low Iceland pressure. The years of extreme southerly deviation are 1834, 1839–1840, 1845, 1853, 1860, 1865, and 1870. The resultant direction of the wind at Portland, Me., has varied between extreme northerly points in 1876, 1883, 1891, and 1898, and extreme southerly points in 1871, 1879, 1887, and 1895.

The tendency for the 7-year period to predominate in higher latitudes accounts for the irregularities in the 11-year temperature variation shown by Köppen and others to characterize the cold temperate latitudes.

A multiple of the 7-year and 11-year periods is one of about 21 or 22 years which has been frequently mentioned by students of cyclical variations.

A MECHANISM OF CLIMATIC CYCLES.[1]

[Review[2] reprinted from the Meteorological Magazine, October, 1920, 55:205-206.]

One of the main lines of research followed in the attempt to forecast the general character of a season several months or a year in advance has been the investigation of "weather cycles." The cycles which we have been asked at one time or another to accept vary in period indefinitely, but the favorites are the sunspot cycle of 11.2 years and a shorter one of approximately 3 years. The sunspot cycle, in spite of a sufficient solar basis, has proved disappointing, its meteorological effects being always small and usually debatable. It is well developed only where the response of climatic to solar conditions is of the simplest, as, for example, on the west coast of Africa, where the rainfall, e. g., at Bathurst, shows three periodicities of 11 years, amplitude[3] 192 mm.; 3.2 years, amplitude 180 mm., and 2.1 years, amplitude 102 mm., together with a "secular variation" corresponding to that observable in sun spots since 1870. Even here the amplitude of the short period nearly equals that of the sunspot cycle. On the other hand, the three-year period is often very obviously developed, and its only apparent cause—the solar prominence cycle—seems insufficient. To meet this difficulty in the case of Java rainfall, C. Braak has put forward in this memoir a "resonance hypothesis." According to this hypothesis, there may be a purely terrestrial cycle of cause and effect, which completes itself and returns to its starting point in about

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[7] Caswell. Results of Meteorological Observations made at Providence, R. I. Smithsonian Contrib. 443. 1882.

[1] Batavia, K. Magn. en Meteor. Observatorium. Verh. No. 5. Atmospheric variations of short and long duration in the Malay Archipelago, and the possibility to forecast them, by C. Braak. Batavia, 1919.

[2] See another review, MO. WEATHER REV., July, 1920, 48:414–415.

[3] *I. e.*, the coefficient a in the formula $R=\bar{R}+a \sin t$.

the same time as the solar prominence cycle. When this happens, the latter fixes the period of the former and greatly increases the range of its phenomena. The best known effect of "resonance" is the semidiurnal variation of pressure.

In the case of Java rainfall the chain of events is briefly as follows: Pressure variations at Batavia coincide with those at Port Darwin in Australia, but the latter have double the amplitude of the former. Consequently, remembering that we are dealing with the Southern Hemisphere, high pressure increases the strength of the east monsoon (November to April) and decreases that of the west monsoon (May to October). It happens that during the former high pressure causes low temperature and is self-sustaining, but during the latter high pressure causes high temperature. This in the course of two years penetrates to the upper air and reduces the pressure below normal. Consequently there is a three-yearly variation of pressure of a "saw-tooth" type, the curve rising slowly for two years and then sinking rapidly for one year. Note that the changes from low to high, or vice versa, can take place only in the west monsoon and the period is thus limited to exactly three years.

It is obvious that a similar sequence of events must take place at many localities near the Equator where conditions are suitable. An example is Lagos, Nigeria, where there is a marked three-year rainfall periodicity. Although pressure data are lacking, we may infer that this is analogous to the case of Batavia, the Sahara taking the place of northern Australia.

A self-regulating system of a different type has been described by W. Meinardus in the north Atlantic.[4] Here ice plays a part. A weak Atlantic circulation means ice at Iceland and little off Newfoundland; this raises the pressure to the east of Greenland and lowers it to the west, causing northerly winds over Baffins Bay and southerly winds at Iceland, so increasing the strength of the Atlantic circulation and reversing the ice conditions. The winter weather in western Europe is known to be influenced by the strength of the Gulf drift, and we may suppose the latter to be affected to some extent by the solar prominence period, acting perhaps only at certain seasons of the year. Hence there are indications of a forced periodicity of three years in the weather of western Europe.[5]

And here, it seems, we have the explanation of why these periodicities so frequently persist for a time, and then break down. For the solar prominence period is not exactly three years, but a few months longer, so that it will gradually outstrip the terrestrial period. After aiding the latter for a few cycles it will gradually come to oppose it, the periodicity will die out, or perhaps skip a year or two, and reappear at the wrong dates, when the resonance is reestablished. This has hitherto been ascribed to a failure of the cycle, but bearing in mind the new principle, it may be possible in the future to forecast these vagaries. Rainfall forecasts based on the modifications of the three-year period are in fact already being issued in Java, and there seems no reason why they should not be equally practicable in other tropical regions.—*C. E. P. Brooks.*

[4] Ann. Hydrogr., Berlin, 1904, p. 353. See further discussion of this and later contributions in MONTHLY WEATHER REVIEW, November, 1918, 46:510-512.
[5] See MONTHLY WEATHER REVIEW, August, 1920, 48:465-466.

EFFECTS OF HEAVY RAINFALL ON PANAMA-CANAL SLIDES.

Among the engineering surprises attending the construction and operation of the Panama Canal may be mentioned the effects of the heavy isthmian rainfall on the troublesome slides that developed in the banks of the canal as excavation work progressed.

It was generally believed by engineers, as well as by the public, that these slides would be most active and troublesome during the season of heavy rainfall. As a matter of fact, the opposite proved to be the case. Practically all of the extensive deep-seated troublesome slides displayed greater activity in the dry season than during the rainy season. The explanation offered by geologists was that the cohesiveness of the material in the canal banks is greatest when the material is saturated by the heavy rains, enabling it to stand up better than it does during the dry season, when it dries out, tending to lose its cohesiveness and crumble under the weight superimposed upon it.

A type of superficial slide of small extent *has been* more prevalent during the rainy season—loose surface material sliding into the canal under the influence of heavy rainfall, but the mass of material involved has been too small to make the handling of these slides a serious problem.

For example, the troublesome *Cucuracha slide* pushed out across the canal channel during the construction period, with a slow, ponderous, glacierlike movement. This slide has been intermittently active from the early construction days down to the present time, but generally more active in the dry season. It gradually spread until it involved an area of more than 50 acres.—*H. G. Cornthwaite.*